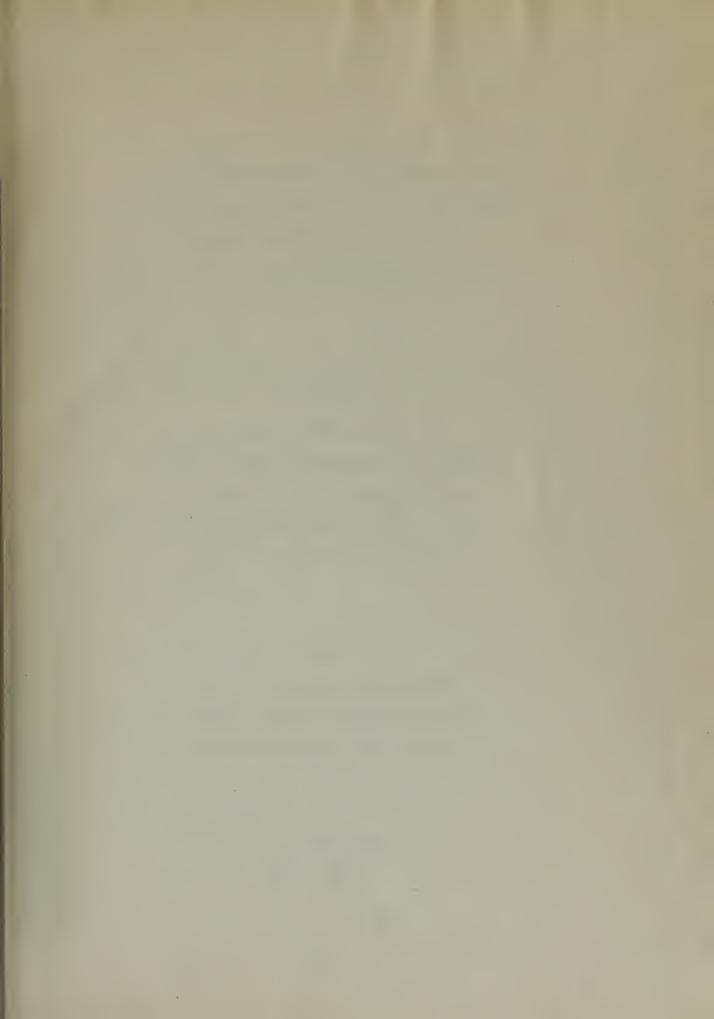
# AN INVESTIGATION OF THE EFFECTS OF AN ASPHALTIC EMULSION AS AN ADMIXTURE ON THE PROPERTIES OF PORTLAND CEMENT CONCRETE

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# AN INVESTIGATION OF THE EFFECTS OF AN ASPHALTIC EMULSION AS AN ADMIXTURE ON THE PROPERTIES OF PORTLAND CEMENT CONCRETE

## A thesis

presented to the faculty of
Rensselaer Polytechnic Institute
in partial fulfillment of the
requirements for the degree of
Master of Civil Engineering

by

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Troy, New York
June, 1948

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### INTRODUCTION

Concrete construction has assumed a major position in modern civil engineering design. Because of its flexibility of use, architectural values, and general availability concrete is used even in instances where it might be inferior in some respects to other materials and methods of construction. Consequently, the general subject of improving concrete mixtures has been given considerable attention.

The idea of experimenting with bituminous admixtures in concrete is not original with the authors. Previous investigators have made thorough studies of such mixtures as a means of physically waterproofing concrete by the dispersion of the bituminous product throughout the pores of the concrete. Such was the work of Mr. Sanborn and Mr. Taylor, conducted in 1913. Their tests showed reduced permeability with an attendant reduction of strength. Mr. Taylor and Mr. Sanborn used a series of bituminous oils in varying quantities and confined their experiments to one general classification of oils.

In Germany prior to the second World War, considerable work was done on the use of bituminous products in concrete for highway work. German engineers were concerned with the effects of repetitive freezing and thawing on concrete and its strength. References to this work are appended below.

This thesis attempts to expand on previous work and to make a study with perhaps an entirely new object. Full credit

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should be given to Mr. H. J. Grathwol of Silver Spring,
Maryland, for his original idea of using an asphalt emulsion
as an admixture for the purpose of controlling temperature
stresses in concrete. Mr. Grathwol, after his theoretical
considerations, contacted Professor H. O. Sharp, of
Rensselaer Polytechnic Institute, and the subject was deemed
worthy of presentation for a master's thesis.

Complete results cannot be achieved here, however.

Time limitations have fixed the scope of the work. In investigating a subject as broad as the use of admixtures in concrete, various arbitrary choices have to be made in order to reduce the variables. In the types and kinds of asphaltic emulsions alone there are far too many to give consideration to each. In the kinds of aggregate the situation is no better. Moreover, some of the important tests, notably expansion, could not be performed because they required six months or more for completion. As a result certain tests were selected using known standards and correlating the results on a comparative basis.

After a study of available research material in the Rensselaer Polytechnic Institute library and the Engineering Societies Library in New York City, the writers confined the scope of the investigation to work which it is hoped will add to the present knowledge of asphaltic emulsion as an admixture. The objectives are: to study the reaction between a bituminous emulsion and concrete mixtures by testing the physical properties of the resulting concrete; to determine the percentages

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of emulsion producing the most desirable properties; to study the disperse phase of the asphalt particles; to study air entrainment.

The experimental work consists of a series of tests applied to specimens of varying composition, age, and treatment. Different methods of handling the asphalt emulsion, mixing the concrete, and obtaining consistencies were tried, as is explained below. Whenever possible the procedures recommended by the American Society for Testing Materials were followed. Whenever this was not the case, the reasons for and description of the procedure used are given.

As stated before, the work presented here is necessarily that done in one school semester. The results cannot be complete, but they are intended to be a contribution to a very important phase of the profession of Civil Engineering.

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### PHASE I

# METHOD FOR DETERMINING OPTIMUM ASPHALTIC EMULSION CONTENT

The first test that was made was to determine the amount of asphalt emulsion to be added to the concrete mix. This was done by testing the cement mortar, using as a maximum the quantity of emulsion, expressed as a percent by weight of Portland Cement, until the strength of the specimen was approximately equal to the strength of a 1:3 mortar mix without the admixture of emulsion. It was decided to do this by following the Standard Method of Sampling and Physical Testing of Portland Cement ASTM Designation C 77-40. In this test a quantity of the cement to be used throughout the laboratory work was first sieved through a number 20 sieve. Standard Portland Cement estimated to be about six months old was used. Three series of briquets were made, one with standard Ottawa sand, the second with a sample of the sand to be used for all the tests which was Cow Bay sand with a sieve analysis as given elsewhere in this report. The third series of briquets was made up of cement mortar briquets with percentages of asphalt as follows: One, Two, Three, Four, Six, Eight, Ten, Twelve percent of emulsion. The large range was required since nothing was known of the quantity of emulsion required to give a strength approximately equal to the standard 1:3 mortar mix.

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The first test that eas made was to determine the THE RESERVE TO SECURE AND ADDRESS OF THE PARTY OF THE PAR as expensed t especial estates to be added to the seneral This was done by testing the commat moster, neares as a maximum the quantity of emiliane, expressed so a percent by weight of Fortland Commit, until the everyone of the special was approximately equal to the strength , me talens to studient one tuesday wir refree E: L = To It was decided to do this by following tom og menders Meanon of Sampling no Physical Looking of Portland to antique Designation C 77-40. In this test a quantity of the assent be to week throughout the laboratory week at the store through a number 30 siege. Standard Portland Cement send wer to be alter service old was these. There exists and of quebs very made, one with stendard Octava seat, the second stant and the tol hase ad of bons add to signed a dirty which was Cov Bay sand with a sleve analysis as given sizewhere in this report. The third serios of briquets was made or or cement morter originate with percentages of asphalt as Tollows: One, Two, Three, Four, Six, Elent, Icu, Thelve purcent of emilsion. The large range was required since nothing was known of the questity of smilnion required to gave a strongth approximately equal to the standard lto merter cit.

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In mixing the Ottawa sand and Cow Bay sand standard briquets, it was first necessary to determine the normal consistency of neat cement. Normal consistency of neat cement is the amount of water required to cause a settlement of the rod of a Vicat apparatus to a point ten millimeters below the original surface in thirty seconds after being released, following the standard procedure for mixing the samples. Several trial mixes were made until the cement was determined to have a normal consistency with thirty percent water. From the table of percentage of water for neat cement paste of normal consistency against percentage of water for mortar of one cement to three standard sand it was found that eleven and one-half percent was required for the standard briquets. At this point it was necessary to decide whether to use an amount of water equal to eleven and one-half percent of the weight of sand and cement and add the emulsion without accounting for the water in the emulsion or to subtract the amount of water in the asphalt and use an additional amount of water to make up the eleven and one-half percent required. The latter was the method followed using an emulsion composed of sixty percent asphalt and forty percent water. Since the briquet moulds were gang moulds each containing three moulds and three samples each of Ottawa sand standard specimens, Cow Bay sand specimens and each percentage of asphalt emulsion, the following amounts of sand, cement and water were used for each batch cast:

In edular the Obtawa and one Con Day and attended limited of the state of the section consistency of mast cament. Sometakeney of mont Immediate a names of betilipot tabus to James wif of Immeso Attornatelia and dator a of andarange tasky a le sor ser le point the original surface in tolthy account with mains ratesons, following the chartest procedure for circuit the Appende our Little oben von begår Lafts Intered inviores wer determined to have a normal constancy with riding percent ester. The the train of percentage of their for onalization fairest tomobilence Larger to whele Juneau Sample of these trademake swall of resues was to terram tol under to not required the drester lief one but overle said barel and of granaposo sen 31 onios sino \$4 . Matorio oranalis and but myole of launch teder to Smrom on war of reduced appropria the hos prompt and been to deliver and to deliver the notations within a constitute out the sales in the constitute and to see him Theologica but of rades to faccount him downsider of an admittance has severe and on ease of rades to demonit languities. persont required. The Letter man the method follows until en send than compared of state territories and their percome water, Stone the brigary mulds over gang muchts plot home assert to done a signor series but ablinos cards quickerpor standard speciality for his sund specimens and security of of applicit empirical, the following assence of guidalum finique in :Jean gotaf does vol bear wire cotaw

Sand - 450 grams

Cement - 150 grams

Water - 69 ml

The following table gives the amount of water for each percentage of asphalt used.

Asphalt Percent	1	2	3	4	6	8	10	12
Grams of Emulsion	6	12	18	24	36	48	60	72
Actual Asphalt	3.6	7.2	10.8	14.4	21.6	28.8	36.0	43.2
Actual	2.4	4.8	7.2	9.6	14.4	19.2	24.0	28.8
Required Water	66.6	64.2	61.8	59.4	54.6	49.8	45.0	40.2

The standard mortar was mixed following the ASTM procedure by mixing the sand and cement dry and then adding the water. Again there was no precedent to follow in adding the asphalt emulsion so that in the process of mixing the batches, several different methods were tried. First the water was added to the cement-sand mixture, then the asphalt emulsion was added and the mixture kneaded and placed in the mould. A second method tried was to add the emulsion to the dry sand and cement and then add the water. The third method tried was to mix the water and emulsion together in a separate container and then add it to the cement-sand mixture. The last mentioned was found to be most satisfactory although

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40,2	0.15)	. 6.04	6.48	59.44	8.14	8.68	4.00	Esquired Nator

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it was found difficult to achieve a thoroughly homogeneous mass and some evidence of lumps of asphalt in the mortar was discovered in the mixing process.

As each batch of mortar was mixed it was placed in the gang mould on unoiled glass plates. The moulds were oiled with a thin film of mineral oil before being filled with the mortar paste. The moulds used were standard briquet moulds for tensile strength tests.

After moulding, all test specimens were immediately placed in a moist closet at a temperature of 21 0 + 1.7 0 centigrade and at a relative humidity of ninety percent. The specimens were left in the moulds and kept on plane glass plates for a period of twenty-four hours. At the end of this period the specimens were removed from the moist closet and from the moulds and placed under water for a period of six days so that the specimens were aged seven days at the time of testing. The specimens were tested as soon as they were removed from the storage water in a tensile testing machine with the load applied at the rate of six hundred pounds per minute. Briquets which gave strength differing by more than fifteen percent from the average value of all test specimens made from the same mixture were assumed to be faulty and were not considered in determining the tensile strength.

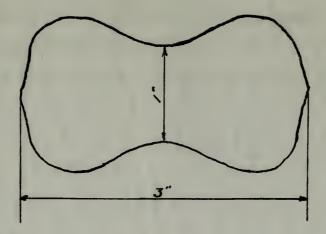
Since the briquets are of the dimensions as shown below, the tensile strength in pounds per square inch was the breaking load of the specimen.

it was found difficult to schieve a thoroughly homeganous at make and none evidence of lumps of negotial to the column was discovered in the mixing process.

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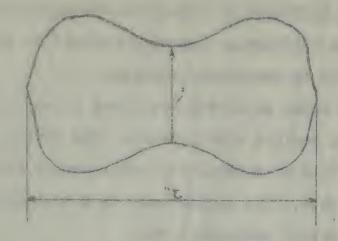
Alter modising, all test specimens many laredleter placed in a noist cloudt at a temperature of 21 " + 1.7" centigrade and at a relative biglity of nigety process. The specimens were left in the monids and topk on lieue willied to the do the .stand thoi-thought to buffen a tol estain teach trine wit noth heven't you summitted add bottom ains and from the months and placed while while for a particle of will day a that the specimes were age seven any and the time of testing. The specimens were bested is such as they mays years william a mi teles stores at a bound of the bettered his to star add to beliege band and stir engone wounds per minite. Erlquete which yave structe official of more than illteen percent from the systage value of all best agactumn wide from the more alwing ours assumed to be slighty and ware down densidered to determinate the tensile . nitramete.

Elmos the briquets are of the dimensions as shown below, the tensile strangth in younds pur square inch see the brake-



The results of the tensile tests are shown in the graph following and it can be seen that the strength decreases as asphalt emulsion is added in larger amounts. Upon breaking the specimens in the tensile testing machine and examining the fracture, it was seen that in many cases the asphalt emulsion had not completely dispersed throughout the briquets leading to the conclusion that only a small percentage of emulsion could be used in mixing the concrete test specimens. Some concern was felt after discovering the segregation of the asphalt in the mortar briquets but from the known fact that the properties of the bituminous emulsion cause it to adhere to moist coarse aggregate, it was thought that this segregation would not be present when using the emulsion in a standard 1:2:3 concrete mix.

As the curve of tensile strength from this series of tests showed a continuous decrease with the addition of from



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zero to twelve percent emulsion it was decided to cast concrete specimens containing zero, one, two and three percent of asphalt emulsion by weight of sand, stone and cement.

mero to twelve percent unitales it was and to nest concrete appearant containing mera, out, two and three percent of sephalt enalsion by weight of send, about and oncent.

# ANALYSIS OF ASPHALT EMULSION USED

Item No.	70 B
Grade	В
Water Percent	45 -
Asphalt Percent	55 ±
Homogeneous	Yes
Specific Gravity @ 77 °F	1.00 ±
Ash Percent	2.0 -
Furol Vis. @ 77 of	30-65
Miscibility	-
Settlement, five days	3.0 -
Stone Mixing	
Setting	Yes
Cement Mixing	100 mile
Screen Test Percent	0.1 -
Demulsibility N/10 Percent	
Demulsibility N/50 Percent	60 ±

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## PHASE II

# PROCEDURE FOR MIXING, MOULDING, AND TESTING CONCRETE SPECIMENS.

Since the tension tests performed on the briquets

(see curve) clearly indicated that increased quantities of
the emulsion decreased the strength properties of the mortar,
it was initially assumed that the same results would hold
true for a concrete mixture using both coarse and fine aggregate. However, it was hoped that with the addition of the
coarse aggregate somewhat better results would be obtained,
because of the known affinity of asphaltic emulsions for
moist stone. This affinity was lacking when sand alone was
used. Furthermore it was also hoped that the segregation of
the asphalt might also be remedied due to this same affinity.
Therefore, it was decided to mould test samples containing
emulsion equivalent to one, two and three percent of the total
weight of sand, stone and cement in the mix.

For test purposes, a series of standard six by twelve inch concrete cylinders and a similar series of concrete beams six by six by twenty-four inches were cast. These series consisted of groups of three samples containing no emulsion, three containing one percent, three with two percent and three with three percent, a total of twelve cylinders and twelve beams. Similar groups were cast and cured for a period of seven days, twenty-eight days and forty-five days. It would have been desirable to have a longer curing period for certain of the groups in order to determine the effects of age on the concrete, but due to time limitations it was

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the smileton deerwood the strength properties of the corer,
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necessary to limit the longest curing period to the aforementioned forty-five days.

The best materials obtainable were used throughout the moulding of the specimens. The fine aggregate was Cow Bay sand from Port Jefferson, Long Island, an analysis of which is appended to this section. In choosing the coarse aggregate, it was felt that a desirable standardization of specimens would be obtained by using a one-size aggregate, even though this would mean a sacrifice of strength. A sacrifice of strength was inconsequential, however, because the results are comparative. Therefore, a clean, sharp, crushed limestone aggregate which passed through a one-half inch mesh screen and was retained on a three-eighths inch mesh screen was used. Portland cement, clean water and asphalt emulsion comprised the remaining materials. The emulsion was obtained from Mr. E. C. Ketchum of the Socony Vacuum Oil Co., Inc., Albany, New York, an analysis of which has been given under Phase I of this text.

Due to space limitations it was necessary to carry on the work of moulding and curing the specimens at the U. S. Naval Supply Depot, Scotia, New York. Fortunately a heated building was obtained as well as a seven cubic foot power mixer. The heated building meant the difference between carrying on this work and abandoning it because of the severe cold weather. The mixer facilitated the accurate and thorough mixing of large amounts of concrete.

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A 1:2:3 mix was used throughout and all quantity
measurements were made to an accuracy of one ounce. Regarding the question of workability, a three-inch slump was
used for each batch. This was obtained by using the minimum
possible addition of water combined with asphalt emulsion.
In this manner the water-cement ratio was kept a minimum
with a consequent maintenance of maximum strength for each
specimen group. By thus allowing for the "break down" of the
emulsion, sufficient water of hydration was assured.

In all cases, an attempt was made to simulate probable field conditions as regards methods of mixing while at the same time devoting stringent attention to laboratory techniques and accuracy. The greatest difficulty in this respect was in the method of applying the asphaltic emulsion. As explained heretofore, during the moulding of the mortar briquets, many methods of adding the emulsion were used. The best of these resulted in vigorously stirring the emulsion into the water and adding the resulting solution to the sand and cement. Water at room temperature was successfully used in this case probably because of the small amounts of emulsion used. Yet, when the same method was attempted with the larger amounts required for a three cubic foot batch, the emulsion broke down and a large lump of asphalt immersed in water was the result. The reason for this action is not definitely known. However, it is the opinion of the authors that large amounts of the emulsion will not go into solution unless the water is heated. Another method, which proved successful, was to add

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specimen gray. By thus allowing for the "break dawn" of the

annialon, sufficient water of hydration was accored.

in all mass, as attempt as made by simulate probably Male conditions on regards we should be a mixing walls at the same time devoting stringers attention to laboratory bacombume and accuracy. The granbest difficulty in this respect mas in the estino of applying the asphaltic sectator. As explained meretofors, daring the moulding of the corter orderets, many sands to deed out . bean ever melalane and aminto to should resulted in vigorously stirring the emission into the water and edding the resulting solution to the sant and tabbe be-Cater at room temperature we succeedily used to this case probably because of the small emunic of smillion seed. Ist, whom the same nethod was attempted with the larger amounts reculred for a three cable foot buboh, the emiliate broke sal and toler of bestmant dispess to come agast a new grot result. The resease for this section is not definitely brown. However, it is the spinion of the encourage and at it prevent of the emiliator will not go into solution unless the voter is bested, Anathar method, which proved successful, see to sad

the required amount of emulsion to the wet mix. Satisfactory distribution was thus obtained with no visible segregation in the wet concrete from the mixer. The resultant success in the use of this method is most probably due to the affinity of the emulsion for wet stone. This method was deemed more desirable than heating the water since it more nearly simulated the probable field method. It was hoped, at this point, that due to this same affinity, the segregation of the asphalt, as noted in the mortar briquets, would not occur in the concrete. A further discussion of the possibilities of adding asphaltic admixtures is included in the conclusions to this thesis.

In moulding the concrete beams, wooden forms were used, whereas for the cylinders standard six inch by twelve inch steel moulds were used as well as six by twelve inch card-board cylinders procured from the Cleveland Container Corporation, 601 West 26th Street, New York City. ASTM specified methods were used in that the concrete was poured in three equal layers and each layer was rodded twenty-five times throughout its depth. In conjunction with this, the sides of the wooden moulds and the cylinders were tapped with a maul in order to assure that the concrete would adhere to the sides of the moulds and voids would be eliminated. The excess concrete was struck off the moulds and the surface finished with a minimum of troweling.

The specimens were cast during the period from March 6, 1948 to April 3, 1948. The forty-five day samples were cast first, then the twenty-eight day samples and finally the

the required enount of emulsion to the met out. Settinger, electronists was thus optimized with mo visible expression in the set concrete from the miner. The resultant errouse in the use of this action is most probably due to the efficienty of the emilsion for wet stens. This estimate was assembly appropriate the meating the mater almost to not a certificate the probable tield action. It was nowed, at this coint, the deprecation of the whell, at the serverium of the whele at the congress.

In acquiring the concrete beaus, wooden forms were used, whoreas for the cylinders standard wis incu so selve inch stand stand monids were used as well as his by trelve inch cert-board sylinders procured from the Cleveland Scotchief Calporation, odd west 26th Street, Mrs tork city. ASTA appetited methods were used to that the concrete was poured in three calculations and tach isper was roaded testing-live that three chrooghout its depth. In conjunction with this, the sides of the wooden moulds and the cylinders were tesped with a mult in order to assure that the concrete would adhere to his sides at the moulds and rolds would no alialmeted. The excess concrete was struck off the moulds and the earling.

The specimens were dust Caring the puriod from march

A, 1943 to April 3, 1942. The forty-five day easylet ware

const first, then the beauty-eight day samples and firstly has

seven day specimens. All specimens were removed from the forms within from twenty-four to forty-eight hours after pouring. Curing was accomplished by two methods: one was to completely cover the specimens with sand which was kept wet continuously and the other was by wrapping the specimens in wet burlap sacks, keeping them continuously wet also. All specimens were cured in this manner until the day of testing.

After the specified curing periods the specimens were transported from Scotia, New York to the Materials Testing Laboratory at Rensselaer Polytechnic Institute, Troy, New York. The concrete beams were tested for bending strength at the extreme fiber. Since all specimens were of exactly the same dimensions, the results are reported herein as simply the breaking load. A hand-balanced Olsen Testing Machine was used throughout the tests. Each beam was centered on two knife edges spaced at a distance of eighteen inches. A third knife edge was attached to the movable head of the machine and bore on the center of the beam, twelve inches from each end. Flat steel plates two inches by eight inches by one-quarter inch were inserted between each knife edge and the beam in order to prevent gouging of the beam by the knife edge. A linkage type strain gage with a linkage ratio of ten to one was connected between the movable head and the stationary supporting arm of the machine in order to give deflection readings of the beam centers. The clutching arrangement was set to give a head travel speed of 0.05 inches per minute.

sower ory specimens. All appeirums were resorred from the forms within Iron towary-loan to formy-enght hade after powering. Curing wie sectoralished by two attends: one end to completely cover to apperiment with seat water and ones are well and continuously end the other well by artsping the sectors. All most burisp sector, howping them continuously met also. All specimens were cured in this minuse model the dep of testing.

After the specified puring periods was speciment were trunsported from Ecotia, New York to the Leterial - Testing Laboratory at Honseplace Folytechnic Institute, Irit, New York. The ognerate beams were tested for tenting strength we the extreme fiber, Since til specimens were of exactly the same almometons, the results are reported hards as slooly bus breaking towd. A bend-behanced Olsen Testing Sanhing was deed throughout the tests. Hack beam was centered on two waite a proper measure to constate a te benega reade often her agines will be hear aldeven out at buinding any ages which Dogw on the center of the bear, twelve inches from veen one. Fire sevel places two inches by sight inches by one-querter Lach were inserted between such units edge and the pour in order to prevent coupling of the beam by the boars adde. Linksgo type strain tage with a Linkago ratio of ton to one was connected between the covable head and the start onery nolvosileh swip of tebro at animose and to are addressum castings of the coarsecert. The clatering arrangement was not be give a head travel sound of 0.03 inches per minutes. The test cylinders were tested on a standard Olsen Compression Testing Machine with the load applied at the rate of five thousand pounds per minute. Each cylinder was capped before testing with Plaster of Paris in order to give a smooth, level bearing surface on each end of the cylinders.

In view of the relatively recent knowledge of the importance of controlling the amount of air entrained in concrete mixtures, it was desired to determine what effect. if any, asphaltic emulsion would have on this property. The authors were fortunate in obtaining from the Research Laboratories of the Portland Cement Association one of their pressure measuring devices. A complete description of this apparatus with instructions for its use is contained in that organization's Bulletin 19 entitled "Procedure for Determining the Air Content of Freshly-Mixed Concrete by the Rolling and Pressure Methods" by Carl A. Menzel. This method is easier to apply and more accurate than the gravimetric method. As each batch of concrete, plain and with various percentages of emulsion was taken from the mixer, a test was conducted to determine the air content and the results are reported herein. Before use, the apparatus was calibrated for the area in which the tests were conducted.

The tast of the colling Sacries with the Love special Olers compression Touting Sacries with the Love special special special colliner sate of five becomes a second point to par minote. Asch cyllower as capped before tosoing with Plaster of Peris in order to give a smooth, Level bearing surface on michigal of une spilinders.

In view of the relatively recent grown deep of the at her latter at to Jamesta ship and for smooth of the state of the compresse mixtures, it was desired to determine what already if any, aspinaltic ampleton would have on this court, The antiport were fortunate in obtaining from the avenual below by the Porting Committee of the service of th dank of building of our all tol smolfharmant diffy enterings -nterested not enumerous to neitition of attention a faction from the ing the sir Content of Stenning-Singel Congress to the Soling and Speakure Methodist by Carl A. Acco. 1. This method in market to apply and note admirate than the gravitating mellod, as again patern of committee, plath and uttle vertices to detail them at of mulision out taken from the misses, a tree out committed bergin. Deform the, the apparatus was cultured for the aren in shigh the bests sers conducted.

## SIEVE ANALYSIS OF COW BAY SAND Used In Moulding Concrete Specimens

Sieve Number	Weight Retained	Percent Retained	Percent Passing
8	1.000	2.79	97.21
16	6.563	18.34	78.87
30	10.563	29.50	49.37
50	13.563	37.85	11.52
100 ,	3.563	9.95	1.57
Passing		1.57	
	35.815	100.00	

## CLEVE ANALYSIS OF CONTROL PART PART

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V7.23	RV.S	1,000	8
78.87	V. CI	206.0	01
YEAR	2.4.50	10,063	0
12.12	₹8.7E	33.563	50
TELL	Ç	3.565	100
	5 = 1	808	Parsing
	200,000	33,815	

#### PHASE III

#### FREEZE-THAW TEST OF CONCRETE SPECIMENS

With the knowledge that entraining an optimum percentage of air improves the durability of Portland cement concrete, it was felt that valuable data could be obtained from a freeze-thaw test. As far as the authors could determine no standard laboratory test of this nature was available at the time. A simple test was devised therefore, which consisted of subjecting three inch by six inch test cylinders to repeated freezing and thawing. The cylinders were placed in a refrigerator at a temperature of 5 of for a period of twenty-four hours. They were then removed and placed in an oven at a temperature of 120 of and left therein for the same period. After three such cycles, this test was interrupted and compression tests were conducted, the results of which are included elsewhere in this text. The tests indicated that the strengths of these samples compare with those of the normally cured specimens. There was no weight reduction at this time and no visible scaling or spalling. This was as expected. A much greater number of cycles would be needed for conclusive results.

### PENER JII

### PRESENTED THE OF CONCESS SPECIOUS

-req similing to animisary interested to optimize per-Junese challent to willistered out savengel the lo sanimal concrete, it was felt that valuable cats conic be surafined Wood execution and as the sale and add -specific mort the sample ains to feat yearspool branches on enterestab aveilable at the time. A simple test was deviate the reductions whiteh constated of sucjective during inch by six lach land sylinders to repeated freezide and thanker. The cylinders were placed in a refrigerator at a requirement of the form a seriou of to only-four moure. They were last to noire mirayan fini dan to our to out to orbitate and a serve me at becala for the same meriod. Alter three cause eggines, this tent -interrupted and compression tests such committed, the visuality of mitch are included eleganers in this term. The tries indicated that the strong tap of theer samules compare with those of the normally cared specimen. I'm as no welcar reduction at this time and no wishes souling or spalling. This was as expected, A made probler namber of cycles would be needed for conclusive results.

### SEVEN DAY TENSILE STRENGTHS OF STANDARD BRIQUET SPECIMENS

## CAST February 17, 1948 TESTED February 24, 1948

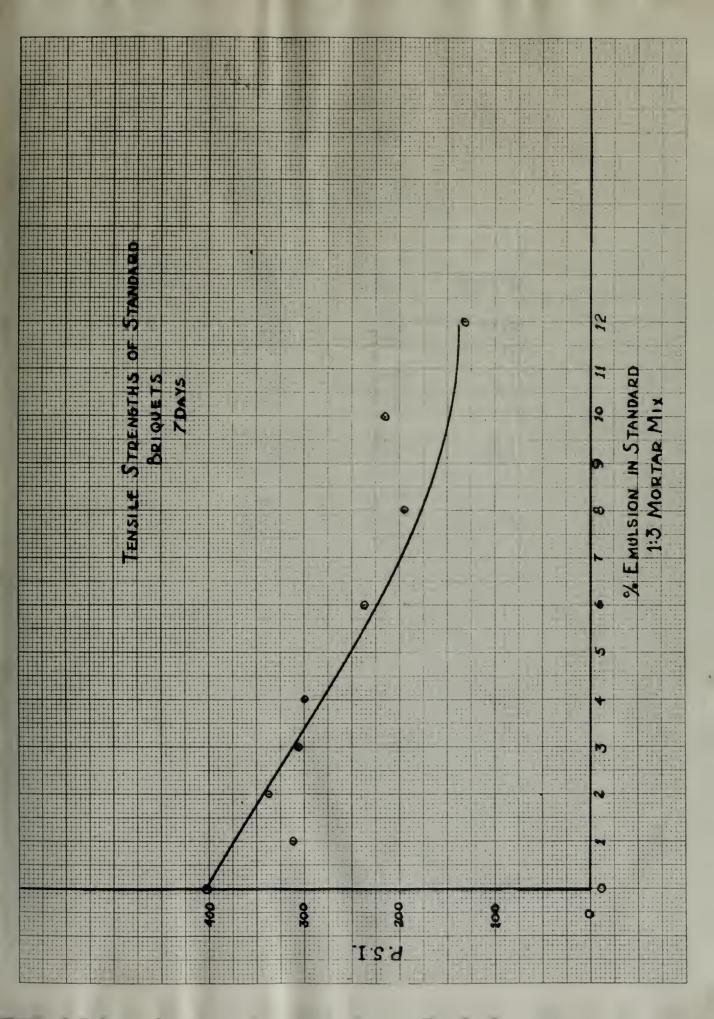
Type	Percent Asphalt	Sample Number	Tension P.S.I.	Average
1:3 Mortar Mix Ottowa Sand	0	1 2 3	266 264 27 <b>5</b>	268
1:3 Mortar Mix Cow Bay Sand	0	1 2 3	403 406 401	403
	1	1 2 3	304 369 274	316
	2	1 2 3	31 <b>5</b> 329 362	33 <b>5</b>
	3	1 2 3	249 340 325	30 <b>5</b>
	4	1 2 3	298 316 287	300
	6	1 2 3	218 295 190	234
	8	1 2 3	185 180 230	198
	10	1 2 3	202 238 224	221
	12	1 2 3	181 106 102	129

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TriTIS Semestry 24, 1948

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335	115 329 360	400	Ø	
305	249 545 345	į	ę	
ont	304 316 287	200	4	
ALE	205 205 205	48.0	-	
1.90	THE	が設定	6	
ISS	SOL	100	3.0	
903	191 100 100	385	13	





COMPRESSIVE STRENGTH

of
SEVEN DAY CYLINDERS

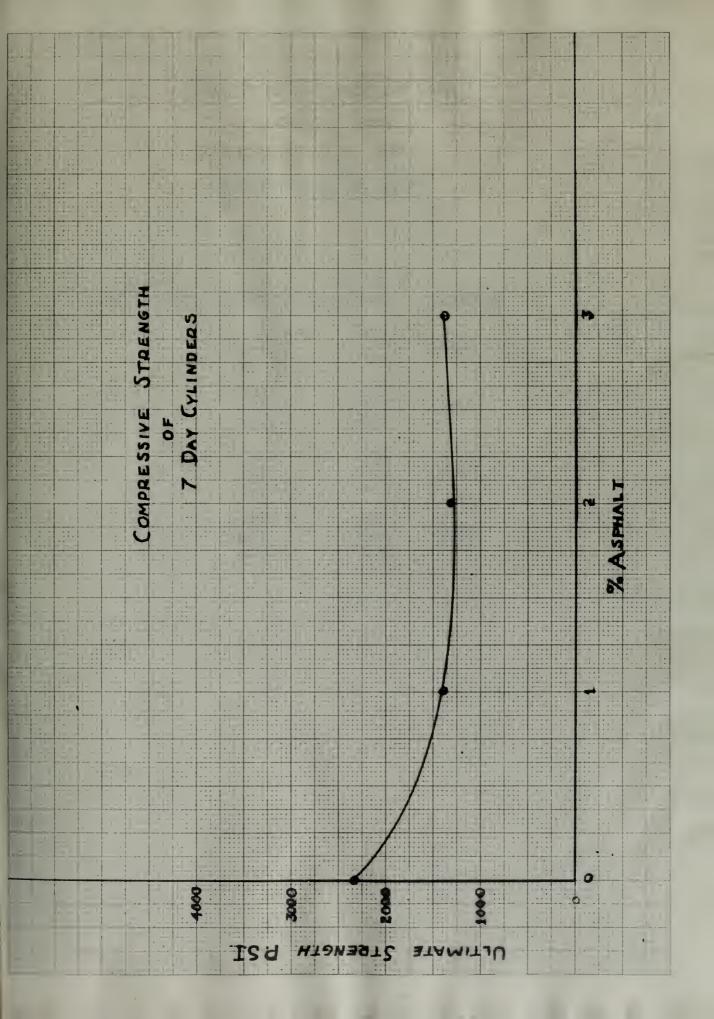
CAST April 3, 1948

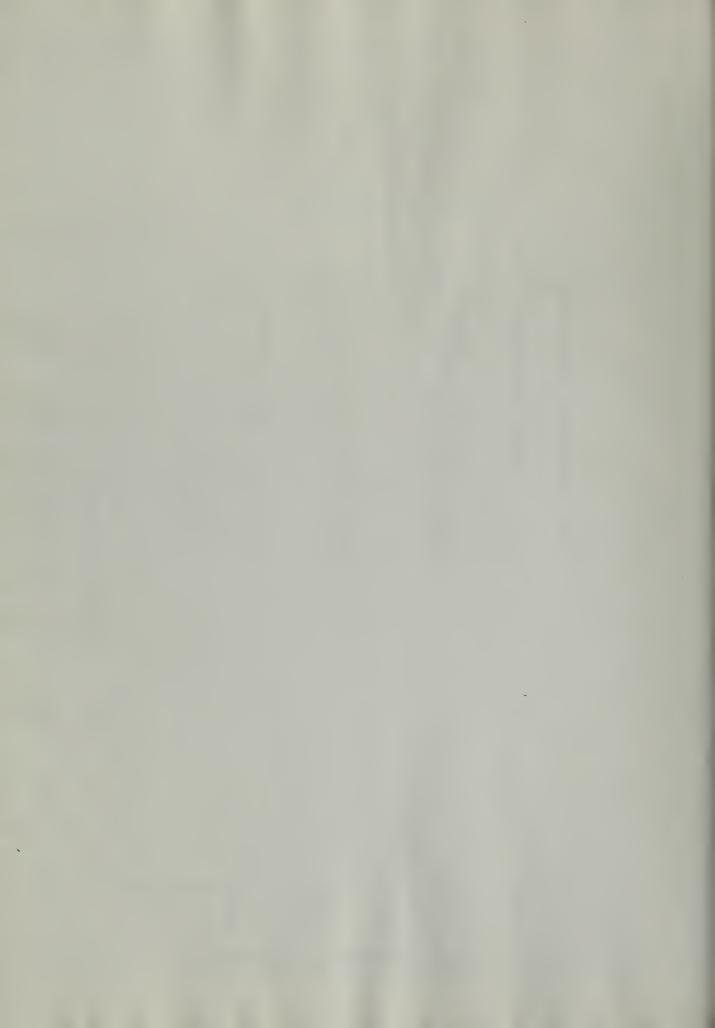
TESTED April 10, 1948

Percent of Asphalt	Breaking Load	P.S.I.	Average
0	63600 lb 69200 64600	2255 2450 2290	2332
1	37600 41300 39000	1221 1462 1381	1391
2	36600 36600 31100	1297 1297 1100	1231
3	39000 39000 39500	1381 1381 1400	1387

CONFRESTIVE STILLIONS
SEVEN LAW CYLLACERS
EAST ASTLE J. 1948
TESTED ASTLE 10, 1948

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SEES	2455 0855 0855	69600 1h 69200 64600	v
1391	1261	37600 A1300 39000	1
12)1	TOOL 1100	Jew 00 34800 31100	Š
ARET	1361 1381 1400	29000 39500 39500	





## DEFLECTION AND BREAKING LOAD SEVEN DAY BEAMS

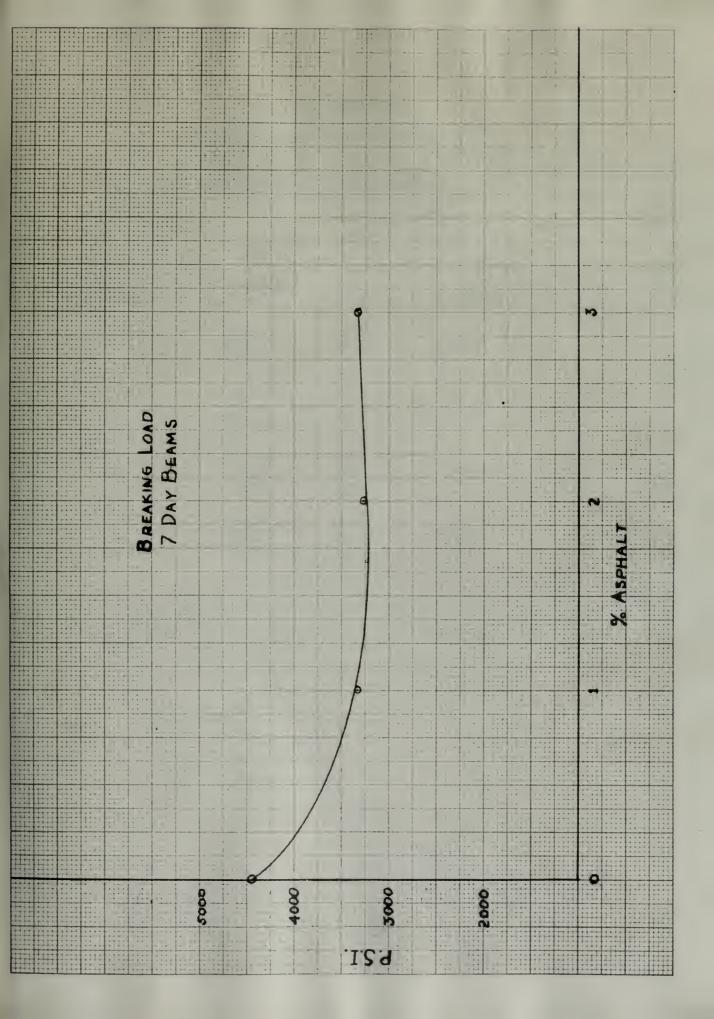
CAST April 3, 1948

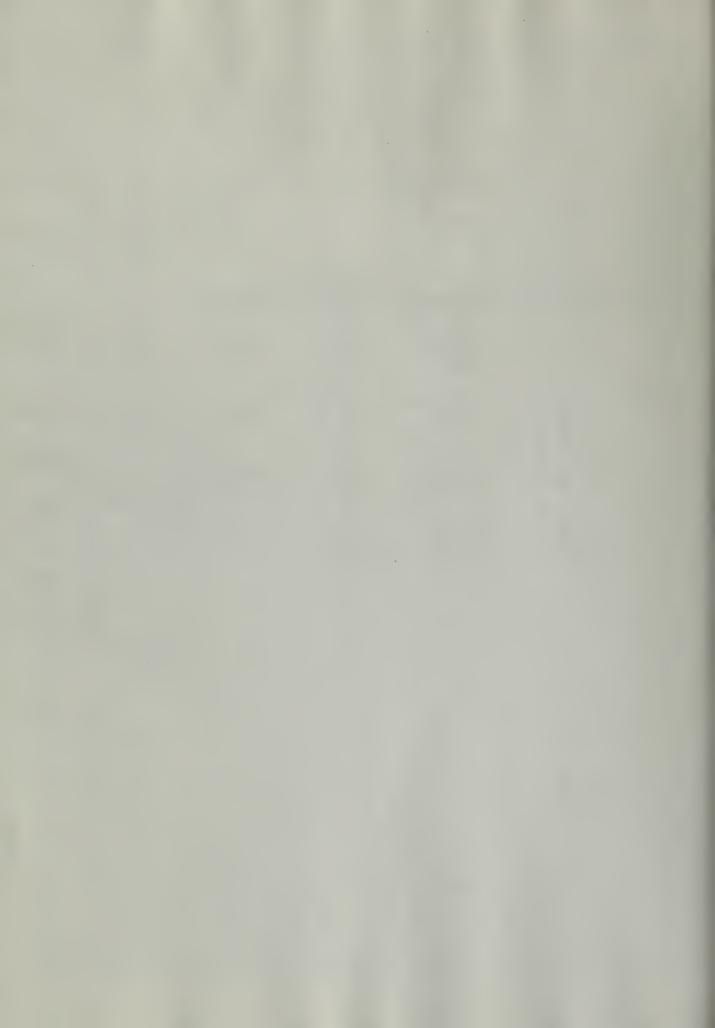
TESTED April 10, 1948

Percent of Asphalt	Deflection	Breaking Load	Average
0	.055 In. .085 .060	3600 4870 4800	4423
1	.065 .055 .055	3350 3350 3230	3310
2	.080 .070 .090	2750 3360 3670	3260
3	.055 .070 .060	3075 3440 3570	3362

# DEFLICTION AND ENSARING LOAD SHYEN DAY BEASE CAST April 3, 1948 THETED April 10, 1948

TOV	Broding	Deslagtion	Porcont of Landers
ESILA	9600 4870 4800	.085 In.	ø
OICE	1350 1350 1350	230. 230. 230.	L
DASE	2750 3570	DBC. DFO. DFO.	£
3302	75.7	070.	3





## COMPRESSIVE STRENGTH of TWENTY-EIGHT DAY CYLINDERS

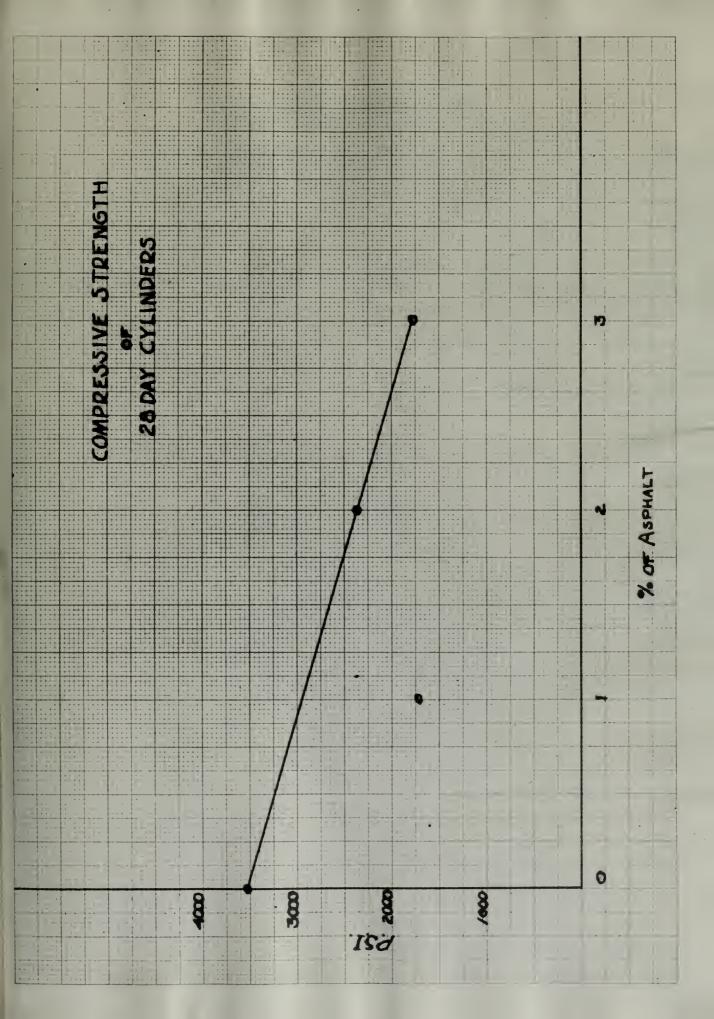
CAST March 12-13, 1948 TESTED April 9-10, 1948

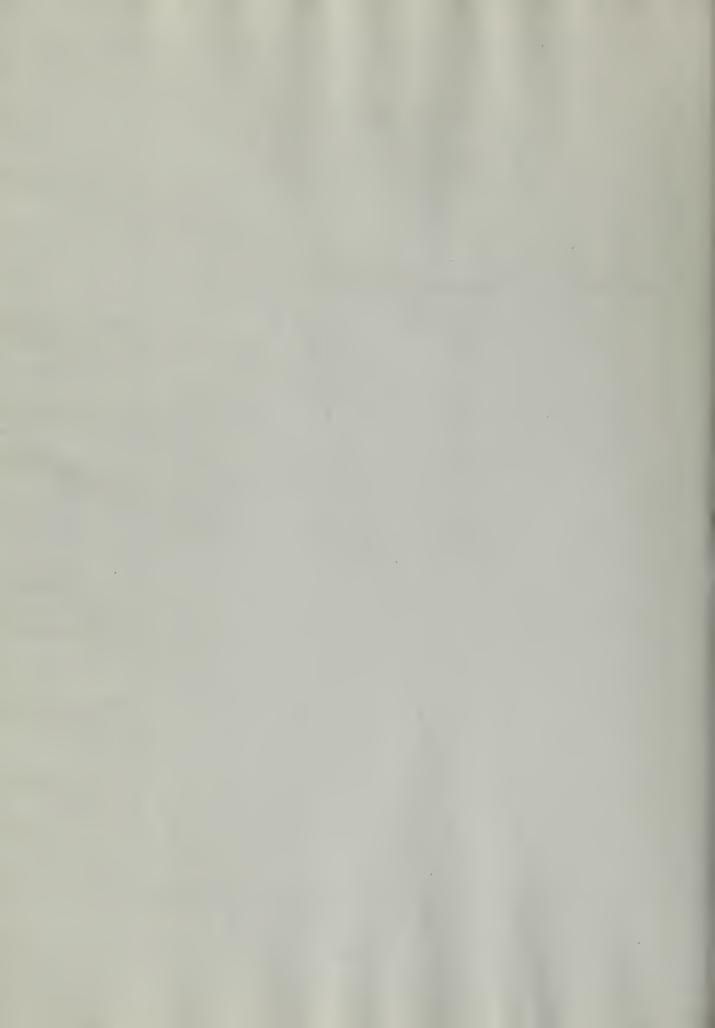
Percent of Asphalt	Breaking Load	P.S.I.	Average
0	98400 100500 99 <b>8</b> 00	3480 3560 3535	3525
1	48400 48000 48900	1750 1700 1730	1726
2	72700 66600 63 <b>5</b> 00	2575 2360 2245	2393
3	52900 50000 47700	1870 1770 1690	1773

## TWISTY-LOST DAY CILINDIAS

CALT Merch 12-15, 1945 [2010] April 2-10, 1945

<u> </u>	F.B.I.	Beod	Percent of Acchalt
3525	3550 3550 3535	98400 100500 99800	.0
2726	1750 1700 1750	00084 00084 00084	1
2393	2575 2200 2215	7.700	2
CMAT	1.170 1.270 1.270	52900 50000 47700	3





#### DEFLECTION AND BREAKING LOAD TWENTY-EIGHT DAY BEAMS

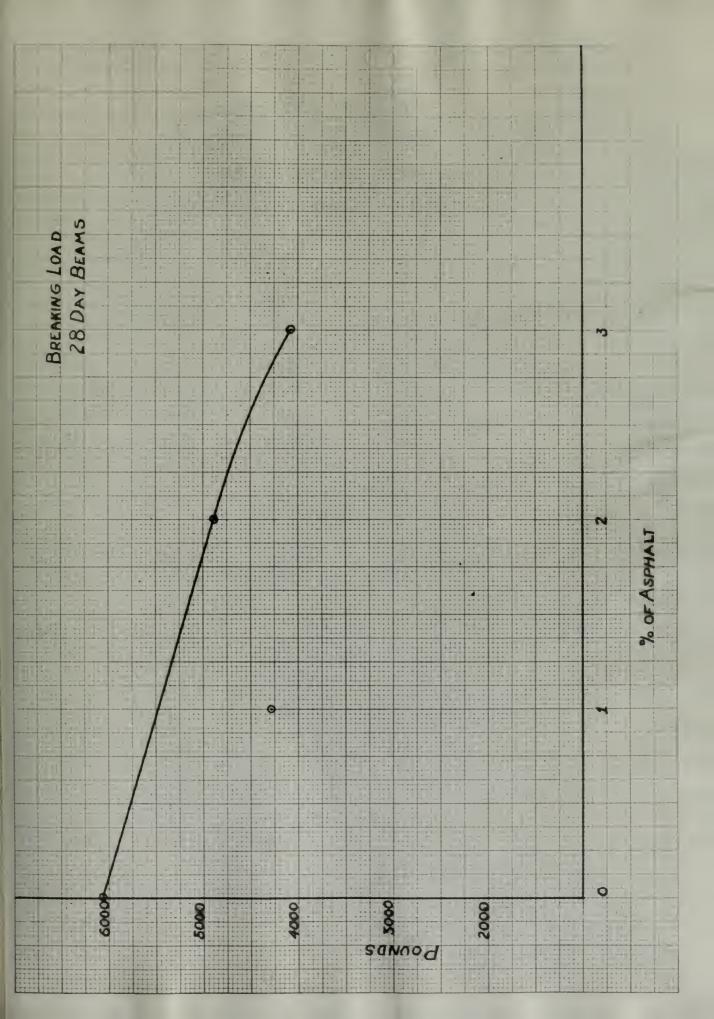
CAST March 12-13, 1948 TESTED April 9-10, 1948

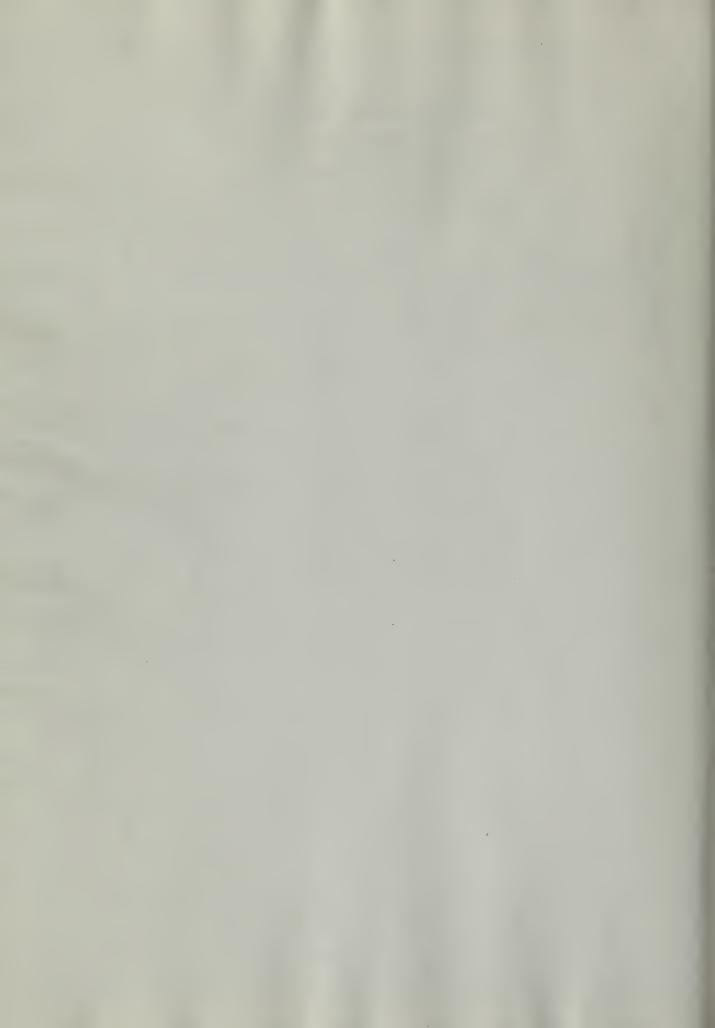
Percent of Asphalt	Deflection	Breaking Load	Average
0	.07 In. .07	6070 Lb. 7150 6078	6074
1	.08 .05 .06	4170 5100 4370	4270
2	.08 .06 .06	5050 4960 4620	4876
3	.06 .06 .05	4078 4080 46 <b>55</b>	4079

### DESERVICE ON BELLAIN LOAD TWENTY-LIGHT DAY SEAMS

C.ST M rch 12-13, 1948

PROTECTA	Broaking	Deflection	Percent of Archalt
6074	5070 Eb. 6078	.07 .07 .07	o
1270	51 0 4.70	80. 80. 80.	1
9687	5050 9=0 4020	80. 20.	2
4079	4050 4050 465)	60. 60. 60.	Ę



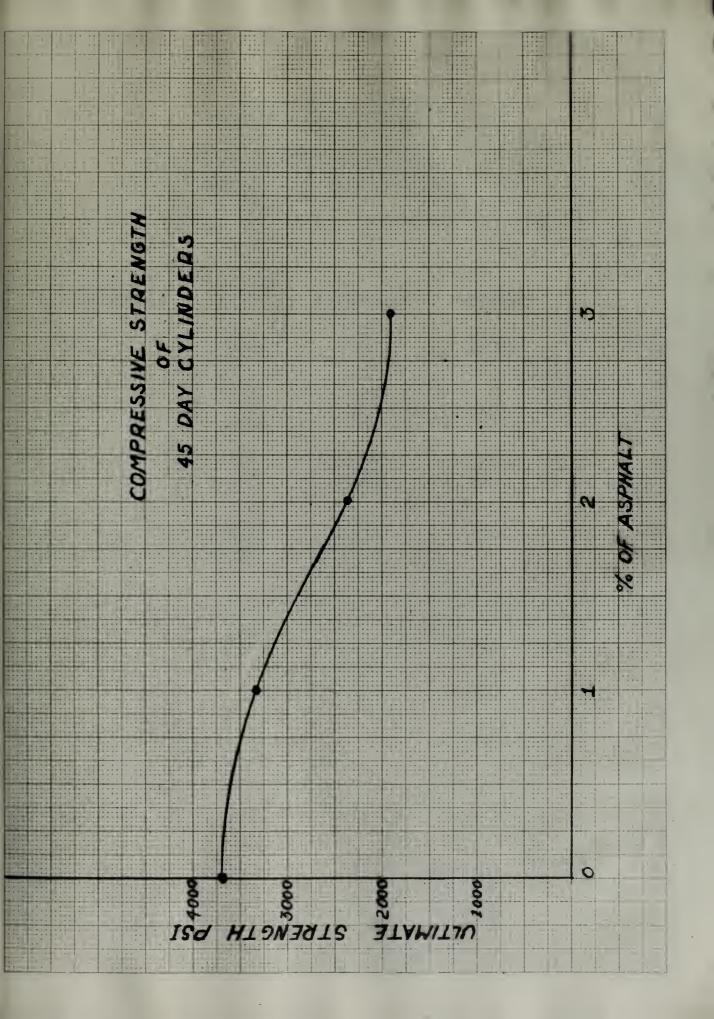


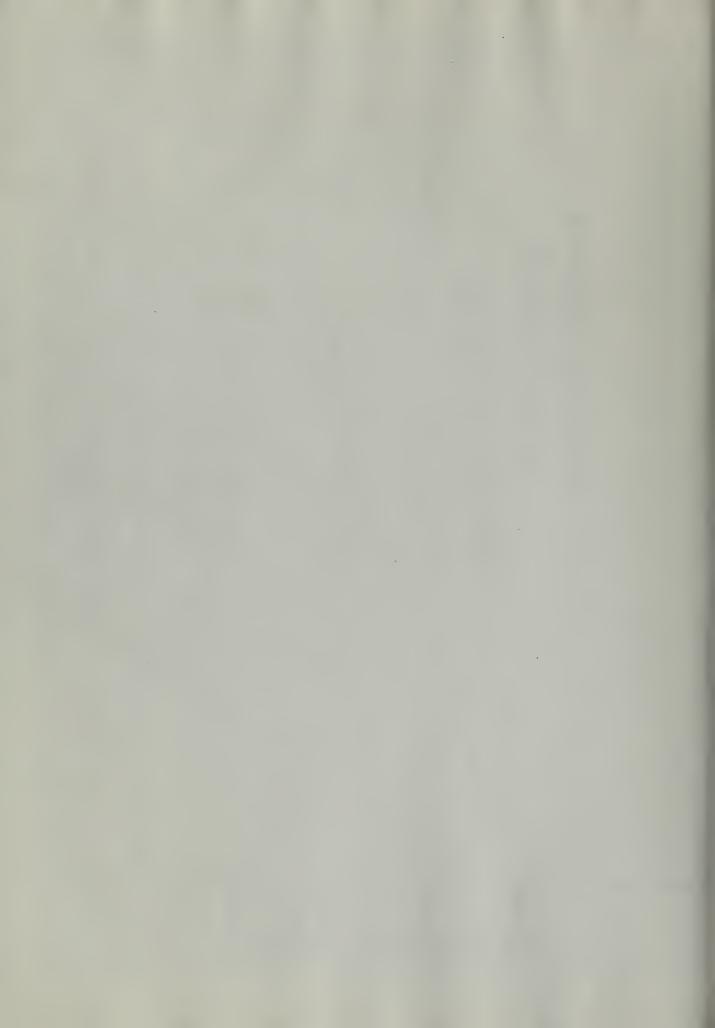
## COMPRESSIVE STRENGTH of FORTY-FIVE DAY CYLINDERS CAST March 5-6-7, 1948 TESTED April 19-20-21, 1948

Percent of Asphalt	Breaking Load	P.S.I.	Average
0	117000 102400 92750	4150 3630 3280	3687
1	103600 83500 96350	3665 2960 3410	33 <b>45</b>
2	66700 63600 69700	2365 2255 2470	2363
3	<b>51</b> 400 <b>53</b> 300 <b>57</b> 000	1820 1890 2020	1910

# COMPRESSIVE STRAWORK OF FOATY-FIVE DAY CYLLYDDERS CAST Warch 5-6-7, 1945 TESTED April 19-20-21, 1946

Maray L	P. S. T.	Breating	Percent
3687	3630 3630 3880	117000 102700 92750	O
3345	3569 2950 3410	10%600 £3500 96350	I
2363	2365	65600 65600 6700	۵
1910	1820 1490 2020	51400 53300 57000	ξ





### DEFLECTION AND BREAKING LOAD FORTY-FIVE DAY BEAMS

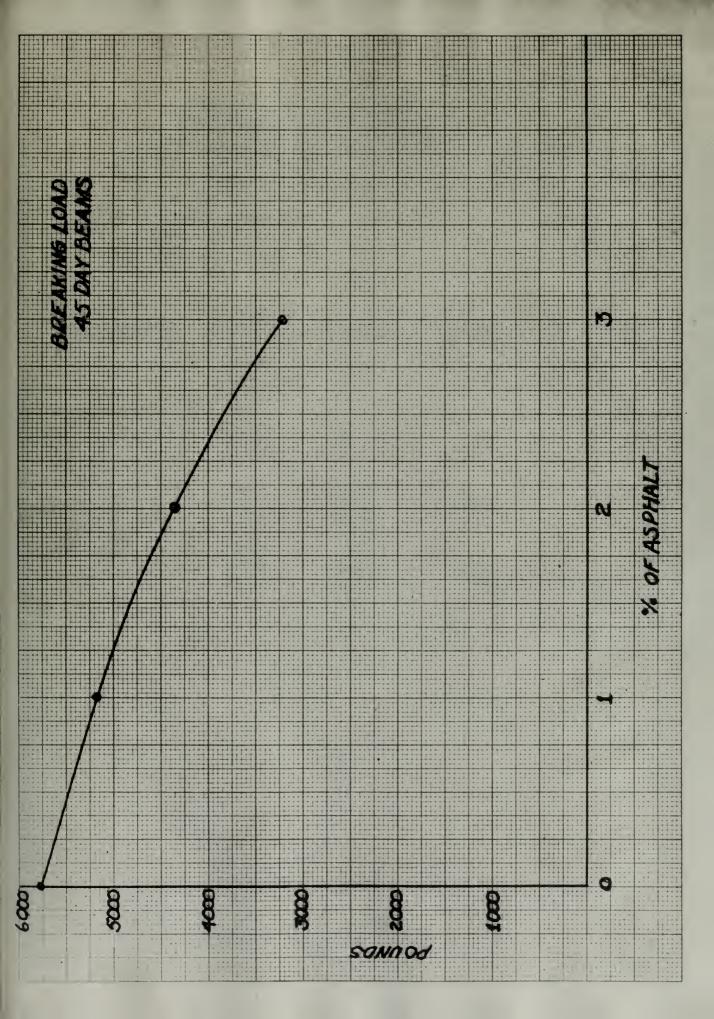
CAST March 5-6-7, 1948
TESTED April 19-20-21, 1948

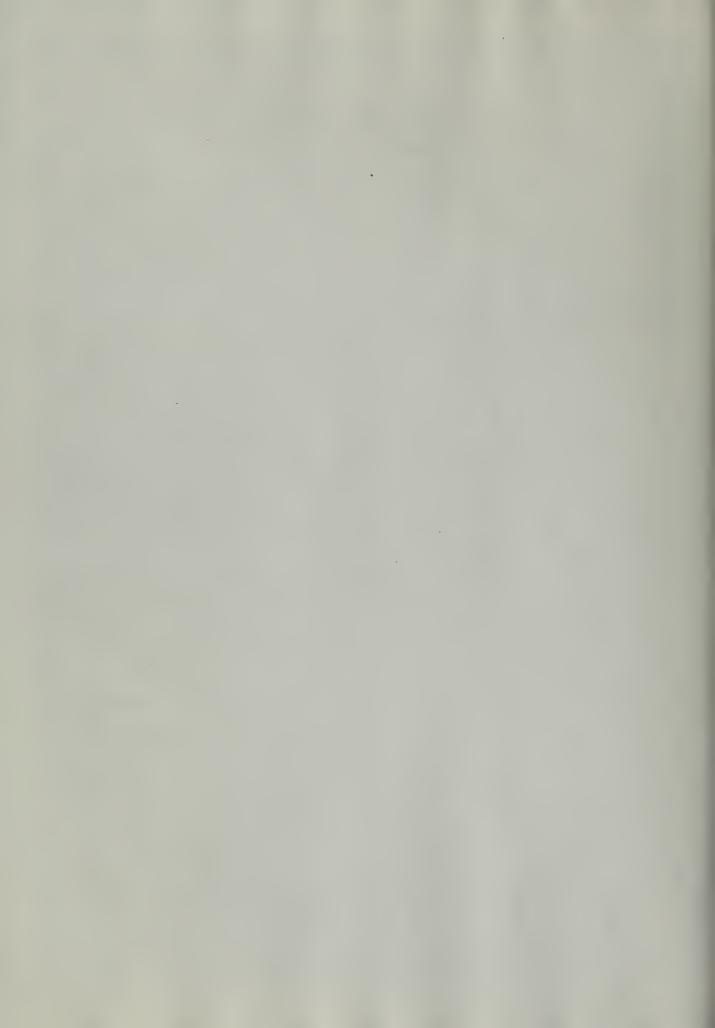
Percent of Asphalt	Breaking Load	Deflection	Average
0	0.100 0.110 0.080	5170 5560 6600	5777
1	0.072 0.070 0.065	5030 5285 6330	5158
2	0.055 0.065 0.065	4000 4700 4 <b>35</b> 0	4350
3	0.060 0.060 0.060	3240 4110 3170	3205

### DEFINITION AND BREAKING COAD FORTY-FIVE DAY BLAND

CAST March 5-6-7, 1946

The State of	Deflection	June 18	freent flangs 10
2777	0600 0710	0.100	0
5158	5030 5285 6330	0.072 0.070 0.065	1
4550	4000 4700 350	0.065	3.
3205	3240 4110 - 170	00.0 00.0 00.0	£





## COMPRESSIVE STRENGTH OF THIRTY-FIVE DAY CYLINDERS AFTER THREE TWENTY-FOUR HOUR FREEZE-THAW CYCLES

CAST April 3, 1948
TESTED May 7, 1948

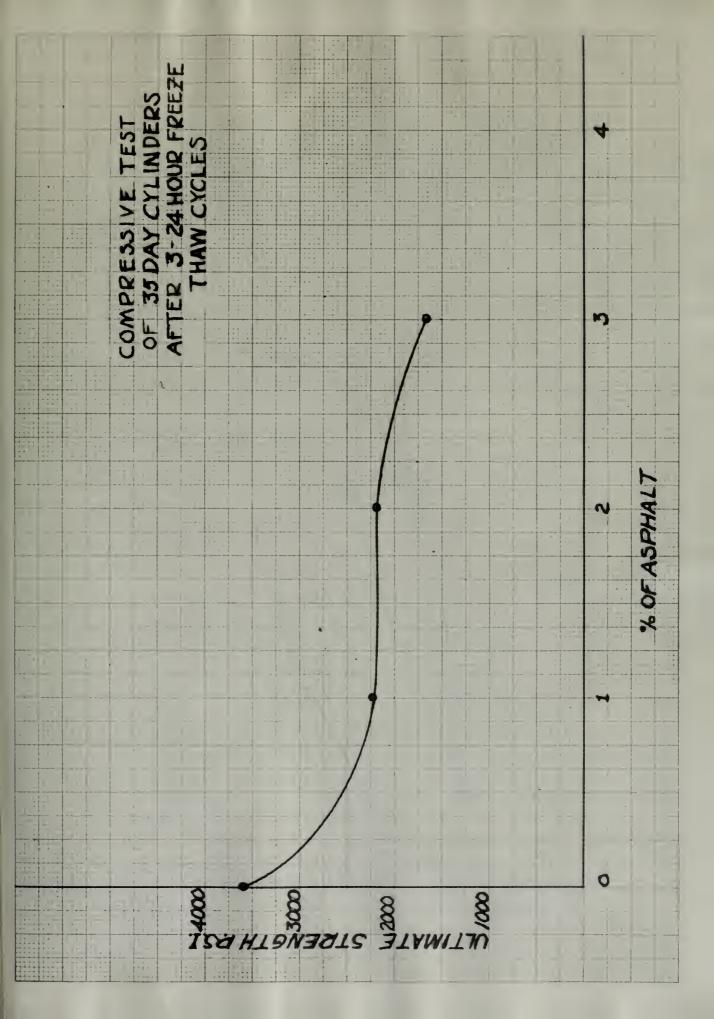
Percent of Asphalt	Breaking Load	P.S.I.	Average
0	22700 26600 27100	3215 3770 3836	3607
1	15300 16400 15800	2165 2322 2224	2247
2	15300 15500 15800	216 <b>5</b> 219 <b>5</b> 2240	2200
3	9000 11900 14600	1273 1686 2068	1675

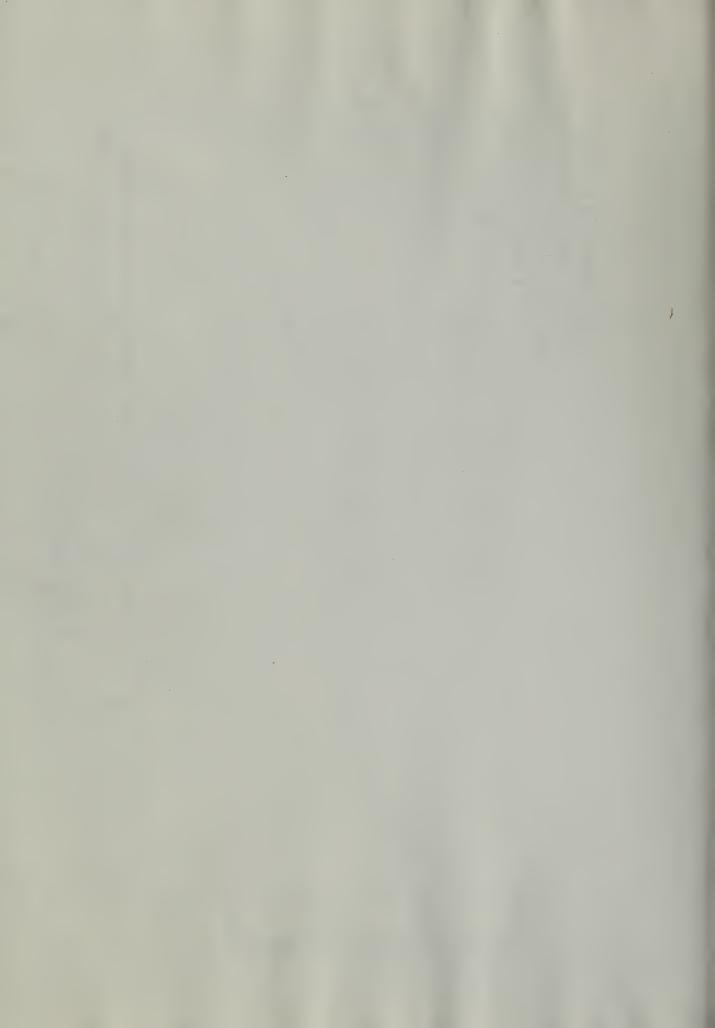
# COMPRESIVE SIPPROTE OF THATI-FIVE DAY OYLIADLES AFTER THESE TWENTY-FOUR HOUR TRIBLE-TEAN OYCLES

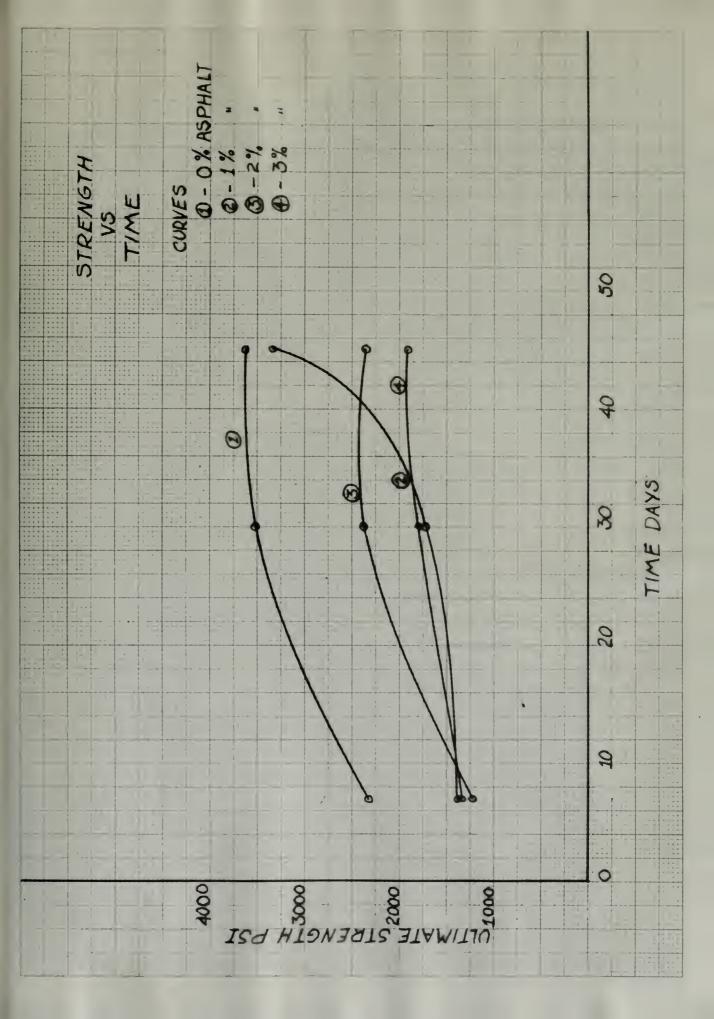
TABL APRIL 3, 1948

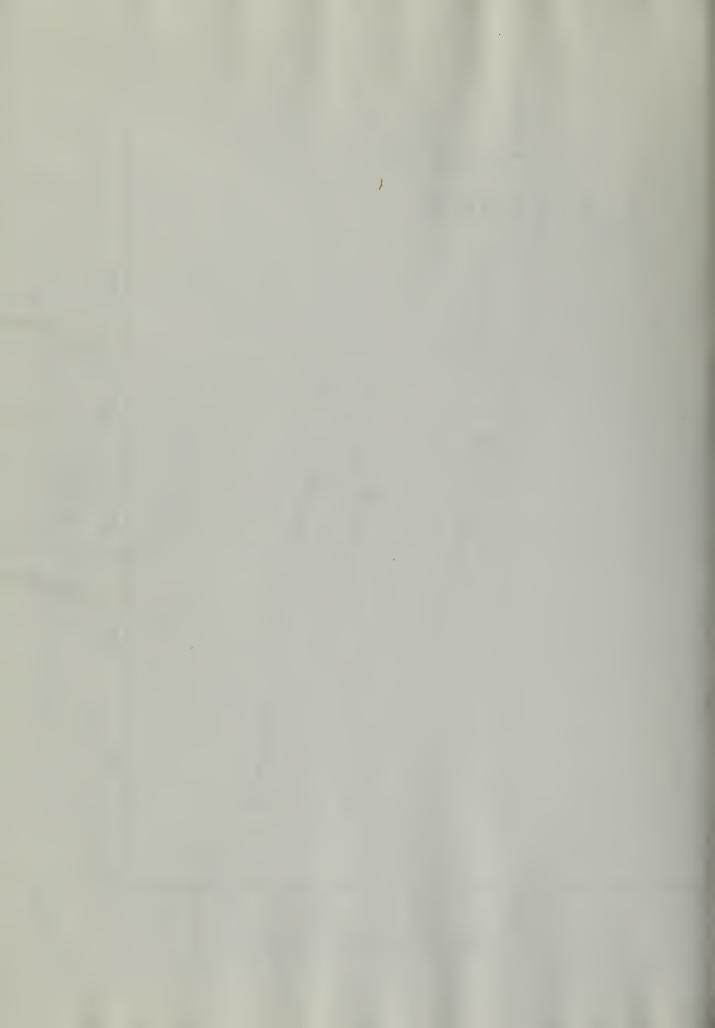
TESTED May 7, 1948

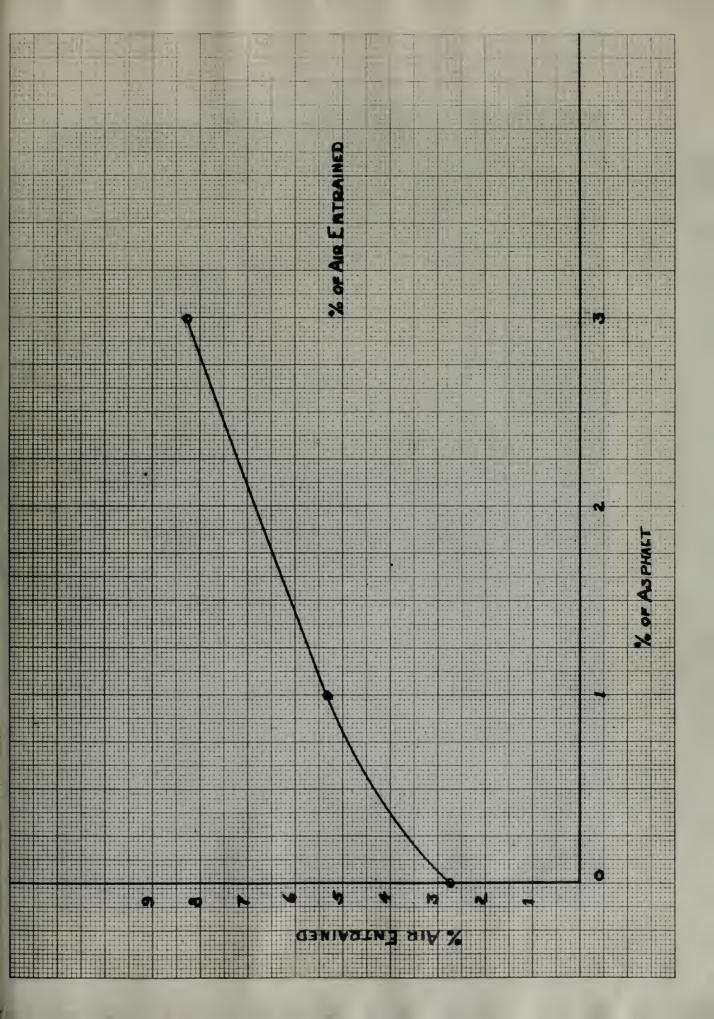
Average	.1.8.9	Breking	Ferent of Asomit
3607	212	23700 2600 27100	0
2247	2155 23.2 2224	15300 16400 15800	Ţ
2200	2165 2195 2165	15900 15900	S
1675	1273 1686 2068	0001T 0000 9000	€.











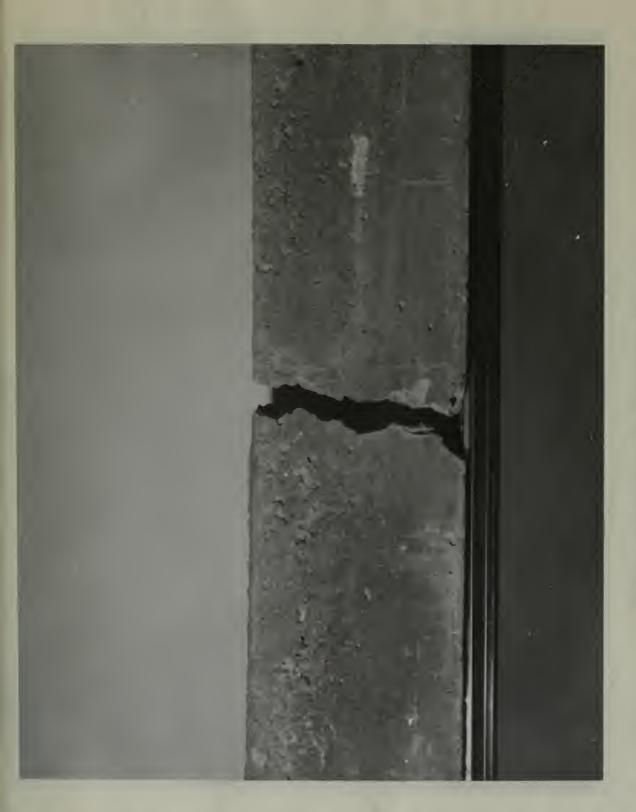




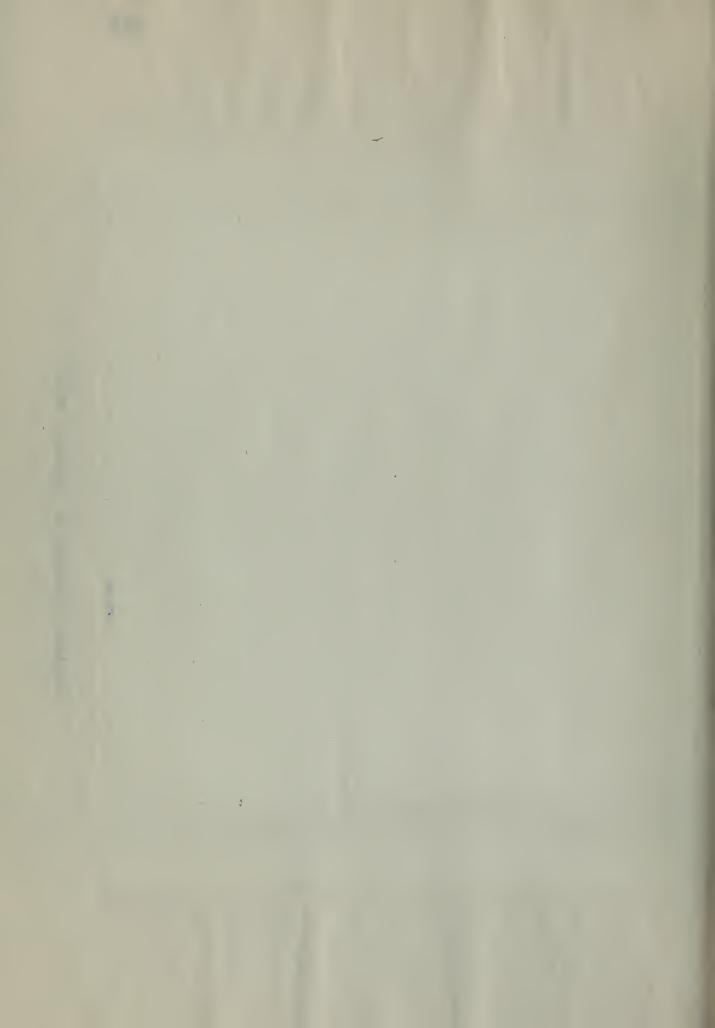
Cross orectonal Fiew of Concrete Deams Containing Administrate

Dura areas are aspitate factions



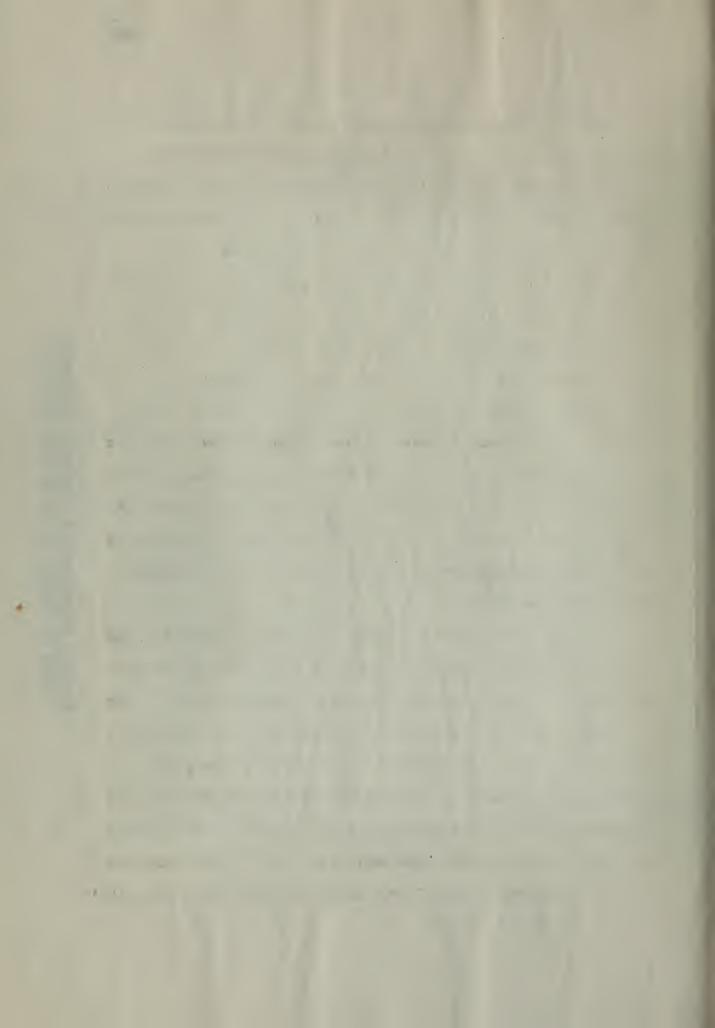


Typical Fracture of Concrete Becaus





Typical fractures of Concrete Cylinders Left To Might: 0, 1, 2, 3 % amulsion



#### CONCLUSIONS

At this stage of the investigation it must be concluded that the results are essentially negative.

The authors, however, feel that the subject warrants further study. While the results shown indicate adverse effects on strength of concrete containing asphalt emulsion, a small reduction of strength can be tolerated if other desirable properties are improved. In general no marked improvement of properties with the exception of air-entrainment was observed. It must be realized, however, that necessarily only one type of emulsion was used; that short-time tests were conducted; that arbitrary methods of mixing were used; and that a particular cement, aggregate, and sand were used. Obviously then, there is much further research to be carried on before the idea of using an asphaltic emulsion as an admixture in concrete should be abandoned.

Further consideration should be given to the selection of the particular asphaltic emulsion best suited, as the particle size in different emulsions ranges from very fine to very coarse, or from about one micron to ten microns.

"An emulsion being essentially a disperse system, its state of dispersion is necessarily one of its most important characteristics. Two aspects of the degree of dispersion are important: (1) The mean absolute size of the particles, and (2) The range size of the particles and their distribution throughout the range size.

#### CONCLINACIONS

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"An emilsion being essentially a disperse system, its state of dispersion is necessarily one of its most important other necessarily one of its most important other aspects of the degree of dispersion are important; (1) The mean absolute size of the particles, and (2) The range size of the particles, and their distribution throughout the range size of the particles.

Many valuable properties could be investigated by tests requiring much longer periods of time. Among these can be included the control of temperature stresses due to the expansion and contraction of concrete through the reaction between cement and aggregate (ref. Paper 2129, ASCE Transactions, Vol. 107, p. 54, 1942).

In practice, the advantages of air entrainment upon the durability of concrete have been exhibited only after years of being subjected to the freezing and thawing forces of nature. The fact that the amount of air entrained in concrete mixtures can be controlled by the addition of definite amounts of asphaltic emulsion indicates that this material will at least accomplish the same result as other commercial products used for this purpose. To obtain maximum information from the proposed freeze-thaw test, a far greater number of cycles should be completed before results can be considered conclusive.

Overcoming the macroscopic segregation of the asphaltic material appears to be the major problem before the full capabilities of the admixture can be realized.

Many methods, applicable to laboratory use, become impractical in the field. It is suggested, however, that a better distribution might be obtained by spraying it over the wet mix and then continuing mixing until the asphalt is uniformly distributed throughout the plastic mass.

tests requiring med lower meriods of time. Among
these can be included the control of temperature stresses
due to the expension and control concrete through
the reaction between remont and aggregate (rot. Paper 2129).
ABOUT Transactions, Vol. 107, p. 54, 1942).

In practice, the adventages of air entrangent open the derective only after the derectives of concrete dave been exhibited only after years of using and the and the angle of neture. The fact that the another of air entrained in remarks white the controlled by the addition of controlled while the addition of definite another of as held to controlled by the case prodit this material will at least accounts to the case prodit as other essective products mad for this parent. To other essective and are the frest made of cycles should be completed before results can be considered conclusion.

nephaltic untertal appears to be the easter problem before the full capabilities of the admixture can be realized. Any methods, spationals to languatory use, become imprectived in the field. It is suggested, however, that a better distribution sight be obtained by approping it over the ret mix and then continuing mixing antil the appoint it over the uniformly distributed throughout the plantic mass.

As has been stated before, in a work of this type, there are many variables which must be considered and certain arbitrary choices had to be made. In view of this fact, perhaps other cements and other aggregates might also be used in future research.

there ere men, veriables wotch must be considered and certain aroterary craises had to be sade. In the of this fact, persons other coments one ctuer as regains eight also be used in intere rescured.

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